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Application for Patent

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בעל אמצאה מכח הדין ששמה הוא
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בעברית (Hebrew): **מערכות אופטיות**

(באנגלית) English: **OPTICAL SYSTEMS**

מבקש בזאת כי ינתן לי עליה פטנט.
Hereby apply for a patent to be granted to me in respect thereof.

*בקשת חלוקה - Application for Division	*בקשת פטנט מוסף - Application for Patent of Addition	*דרישת דין קדימה Priority Claim		
מבקשת פטנט from Application No. מס' Date מיום	*לבקשה/לפטנט to Patent/Appl. No. ______ מס' Date ______ מיום	מספר/סימן Number/Mark	תאריך Date	מדינת האיגוד Convention Country
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המען למסירת הודעות ומסמכים בישראל Address for Service in Israel WOLFF, BREGMAN AND GOLLER וולף, ברגמן וגולר P. O. Box 1352 ת.ד. 1352 Jerusalem, Israel, 91013. ירושלים 91013				

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OPTICAL SYSTEMS

מערכות אופטיות

Field of the Invention

The present invention relates to optical systems generally operating with many wavelengths, and to optical systems used, for example, in communication systems.

Background of the Invention

Many optical systems require the use of a series of wavelengths. These different wavelengths are generally referred to as "channels." For example, Dense Wavelength Division and Multiplexing (DWDM) communication systems exploit numerous different wavelengths in order to increase the throughput of the communication system. Other such systems include Differential Absorption Lidar (DIAL) systems, which are used for monitoring pollutants or small quantities of gases in the air. In these systems, the measurement is performed by transmitting rays having a multitude of closely spaced wavelengths, and afterwards detecting the backscattered rays. Generally, one of the rays, having a specific wavelength, is absorbed by a specific substance on the optical track, and the amount of absorption is measured by the ratios of the amplitudes of the backscattered rays.

In general, each single wavelength is obtained from a single source, which is usually a laser source, and the number of required sources is the number of different wavelength channels. Both the central wavelength of each channel and the wavelength variations, are determined by the properties of a specific source. Thus, in order to prevent overlapping of two adjacent wavelength channels, the spacing between these channels must be larger than the wavelength variations or tolerance of each single channel. The wavelength variations result mainly from temperature changes, but are also susceptible to opto-mechanical instabilities and fabrication tolerances. Since the wavelength range of an optical system is generally limited, the wavelength variations in such systems limit the total number of possible channels.

When operating a system wherein each wavelength channel is generated by a different light source or when there is a need in backup sources, an identical light

source should be available in stock, which is costly. Alternatively, all of the channels could operate with a similar light source which has a tunable wavelength in a certain range and is fixed to a different wavelength for each channel. Here again, the tunability significantly increases the cost of the light source.

Some systems, in which one fiber laser source provided several wavelength channels with equal spacing between them, have been investigated in the past. However, in such fiber lasers, a single output ray is produced which consists of a multitude of wavelengths. Thus, the different wavelength channels are not separated either spatially or angularly and cannot be separately modulated.

Other known systems applied stimulated Brillouin scattering (SBS) for wavelength conversion. However, such wavelength conversion systems change their properties with temperature or strain, since the frequency shift is dependent on the refractive index (namely, $\nu_B = 2nV_A/\lambda$, where ν_B is the frequency shift, n is the refractive index, V_A is the speed of sound and λ is the wavelength), which in turn changes with either temperature or strain. This instability limits the use of such devices, especially in a cascaded configuration, wherein deviations from the desired frequency shifts are accumulated.

In the optical receiver of multi-wavelength communication systems, it is generally required to split the incoming signal (composed of a multitude of wavelengths), into a multitude of channels, each having a single wavelength. This process is referred to as "optical de-multiplexing." Several methods are widely used for de-multiplexing. These include exploitation of diffraction gratings, either inside optical fibers (known as "fiber Bragg gratings"), in a waveguide or in free space, the exploitation of prisms, the exploitation of interferometers, or other spectral filters.

Summary of the Invention

The present invention provides an optical system, which includes a single light source (for example, a laser), from which emanates a series of spatially or angularly

separated rays, each having its own wavelength. The spacings between the wavelength channels can be predetermined and stabilized. These spacings remain fixed during temperature changes and wavelength variations of the input light source. Also, the system provides controllable de-multiplexing methods for separating an optical signal with a plurality of wavelengths into a set of separated wavelengths.

The multi-wavelengths light source device is based on non-linear optical processes, such as acousto-optical effects and/or SBS. In these non-linear optical effects, an incident ray with wavelength λ_i is transformed by means of reflection or scattering into a ray having a wavelength λ_s which is slightly different than λ_i. The wavelength difference λ_s-λ_i is determined by the properties of the acousto-optical device or by the properties of the SBS material, and generally changes with temperature or strain. The acousto-optical or SBS device can be a solid bulk material such as glasses or quartz, a liquid, an optical fiber, or another material with acoustic properties.

In order to obtain efficient SBS devices, certain limitations of the SBS materials and the input ray power should be overcome. Specifically, the power of the input ray should be higher than a threshold value. Generally, when operating with a bulk material SBS device, the threshold is relatively high, so pulse operation is preferably used. However, when using optical fibers, significantly lower threshold power is required. These powers can be readily obtained with continuous wave operation. Moreover, fibers with special characteristics, such as small core cross-sectional area, have even lower threshold powers, so they are more efficient for usage as SBS devices. These fibers include dispersion-compensated fibers (DCFs), or photonic-bandgap fibers.

In order to obtain a series of separated rays, each having a different wavelength, a cascaded configuration of acousto-optical or SBS devices is utilized. Specifically, the output ray of each of the acousto-optical or SBS devices may serve two functions: First, the ray, or a part of it, may serve as an output wavelength

channel of the system. Second, the ray, or a part of it, may serve as an input wavelength to another acousto-optical or SBS device, in order to obtain the next wavelength in the series. Such a cascaded configuration may be repeated many times. To compensate for the power losses in the system which arise due to scattering, and the imperfect efficiency of the various components, it is possible to add optical amplifiers next to (either before or after) each acousto-optical or SBS device, or next to a series of a few such devices.

Generally, SBS devices operate as reflecting devices, so the output ray generally propagates in a direction opposite to the input ray. In order to separate the output ray from the input ray, it is possible to utilize a 2x1 beam splitter or an optical circulator, so that nearly all the power of the output ray is directed to a different direction from the input ray. By selecting proper materials, it is possible to design specific frequency shifts for the SBS process. Thus, one can obtain predetermined spacings.

The embodiments proposed and presented herein minimize the temperature dependence of the system, and thus allow the system to operate with nearly fixed spacings at a wide temperature range. These embodiments include the combination of SBS devices and acousto-optical devices, whose wavelength spacings each vary differently (e.g., one increases and the other decreases) with temperature. Similarly, two or more SBS devices, composed of two or more different materials, some having a refractive index which increases with temperature (positive d*n*/dT) such as quartz or BK7 Schott glass, and others having a refractive index which decreases with temperature (negative d*n*/dT), such as FK52 or PK51A Schott glasses, may be used. In this manner, the total wavelength spacing remains fixed although the individual spacings change with temperature.

Another embodiment of the invention exploits both the temperature and the strain dependence of the refractive index. Here, an optical fiber is wound on a spool. Temperature changes cause two effects: first, according to the fiber material

composition, the refractive index of the optical fiber changes with temperature; second, the strain induced on the fiber, and thereby again the refractive index, changes as the spool expands or contracts with temperature. By a proper selection of the spool material composition, having different expansion coefficients, the expansion, and thereby the strain, are controlled independently of the fiber material. Thus, the two effects (strain and temperature dependence) are designed to cancel each other, leading to nearly fixed wavelength spacing with temperature.

The cascaded system is capable of creating a series of hundreds, or even thousands, of wavelengths. The spacings between every two neighboring wavelengths can be predetermined by a specific acousto-optical or SBS device, so that the series of wavelength may have either equal spacings, or different, predetermined and stabilized spacings. The system can operate either with a continuous wave (CW), single pulse, or repetitive pulses (RP).

As the reliability and continuous operation of optical transmission systems are important, a backup for system malfunctions, which mostly occur in active components, is advantageous. Accordingly, a tunable laser source, or a series of tunable laser sources, may be provided as backup to the multi-wavelengths source. When a failure occurs, the tunable source is tuned either to the first wavelength that is missing, or to the next one, so that, in the worst case, only one wavelength will be missing in the whole system.

A backup to the first source laser may also be provided. Since the amplifiers in the light source operate with multiple pump diodes, their reliability is relatively high, and thus a first source laser is one of the most unreliable members in the system. Thus, another such laser source may be used in parallel. This backup laser source is activated immediately when the first laser source fails, leading to an immediate replacement in case of system failure.

Another embodiment of the invention comprises an architecture which reduces the total number of components. Here, there is provided a multi-cascaded design, in which the output from the Nth stage is input again to the first stage. In this manner, each output ray is composed of a series of different wavelengths. Due to the relatively large spacing between the different wavelengths in the same fiber, these wavelengths can be relatively easily separated by means of conventional optical de-multiplexing devices.

Each output ray, which is spatially separated from the other rays and has a specific stabilized wavelength, can be separately modulated by using a dedicated modulator. Alternatively, groups of output rays can be modulated together by the same modulator, to obtain a broadcast-like transmission.

The active control of the de-multiplexing system is performed by using one of the multitudes of wavelength channels as the control channel. Since the spacings between the different wavelengths are well-known, by locking on the control wavelength channel, all other wavelength channels are also locked, and thus can be readily obtained.

The actuator in the closed control loop slightly changes the properties of the optical de-multiplexer, namely, by slightly shifting each of the output wavelength channels. This is obtained by either using an actuator, e.g., a piezoelectric or magnetic restrictive actuator to tilt, strain or move a grating, or to use such an actuator to slightly tilt or move the output waveguide or the fiber output array, or by slightly changing the wavelengths of the input ray using a wavelength-shifting device, such as an acousto-optical device.

As a result, small changes or deviations in the input wavelengths, caused mainly by small variations in the first laser source, can be compensated for by active control of the optical de-multiplexing system. To compensate for such unknown and relatively slowly varying wavelengths, closed-loop control is utilized. This control

can be based on an actuator, by maximizing the output in the control channel, whose input signal characteristics are well known. Alternatively, this could be performed by receiving the control channel with two detectors having slightly different reception wavelengths, one of which is slightly higher than that of the desired control channel wavelength, and the other of which is slightly lower, and equalizing the output.

Thus, the present invention provides an optical system for transmitting and receiving multiple wavelengths. The transmission sub-system is based on connecting an input ray of light having a single wavelength into a plurality of spatially or angularly displaced output rays, each having a different wavelength, the system comprising an array of a plurality of acousto-optical and/or stimulated Brillouin scattering (SBS) devices in optical communication with each other, whereby variations in the wavelength of said input ray or in temperature or strain of said devices will cause the wavelengths of said output rays to uniformly vary, thus maintaining constant intra-wavelength spacings between said output rays. The receiving sub-system is based on feedback-controlled optical de-multiplexing.

Brief Description of the Drawings

The invention will now be described in connection with certain preferred embodiments with reference to the following illustrative figures so that it may be more fully understood.

With specific reference now to the figures in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention, the description taken

with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice.

In the drawings:

Fig. 1 is a schematic illustration of a stimulated Brillouin scattering (SBS) device;

Fig. 2 is a schematic illustration of an SBS device along with an optical beam splitter or circulator;

Fig. 3 is a schematic illustration of an SBS device along with an optical beam splitter or circulator and an optical amplifier;

Fig. 4 is a schematic illustration of cascaded SBS devices composed of spooled optical fibers, along with optical beam splitters or circulators;

Fig. 5 is a schematic illustration of cascaded SBS devices composed of two different materials, along with optical beam splitters or circulators;

Fig. 6 is a schematic illustration of cascaded SBS devices composed of two different materials, along with optical beam splitters or circulators and optical amplifiers;

Fig. 7 is a schematic illustration of an acousto-optic wavelength-shifting device;

Fig. 8 is a schematic illustration of an acousto-optic wavelength-shifting device along with an optical amplifier;

Fig. 9 is a schematic illustration of cascaded acousto-optic wavelength shifting devices;

Fig. 10 is a schematic illustration of cascaded acousto-optic wavelength shifting devices along with optical amplifiers;

Fig. 11 is a schematic illustration of an optical parametric oscillator (OPO) device;

Fig. 12 is a schematic illustration of a combination of OPO devices and either cascaded SBS devices or cascaded acousto-optic wavelength shifting devices;

Fig. 13 is a schematic illustration of a system for obtaining a multitude (10, in the specific example) of separated rays, each having each a different wavelength, out of a single input wavelength;

Fig. 14 is a schematic illustration of a system for obtaining a multitude (10, in the specific example) of separated output rays, each having a different output wavelength, each of which is modulated by a separate modulator, out of a single input wavelength;

Fig. 15 is a schematic illustration of an optical de-multiplexer system;

Fig. 16 is a schematic illustration of an optical de-multiplexer system having a device for tilting the receiver and a wavelength-shifting device;

Fig. 17 is a schematic illustration of an optical de-multiplexer system having a wavelength shifting device;

Fig. 18 is a schematic illustration of an optical de-multiplexer system having a feedback-controlled tunability;

Fig. 19 is a schematic illustration of another embodiment of an optical de-multiplexer system having a feedback-controlled tunability, and

Fig. 20 is a schematic illustration of a multi-cascaded optical system for producing multiple wavelengths.

Detailed Description

Reference is now made to Fig. 1, which is a schematic illustration of a stimulated Brillouin scattering (SBS) wavelength displacing device 2. An incident ray of wavelength λ_0 propagates from left to right towards an SBS device 2 made of a material 4, which material could be constituted by an optical fiber, a bulk material, a liquid, or other optical material. Due to SBS, a reflected ray with a slightly different wavelength λ_1 emerges back from the SBS material 4.

Fig. 2 shows a schematic illustration of an SBS device 2 with an optical beam splitter or circulator 6, in which, similar to the device of Fig. 1, an incident ray of wavelength λ_0 propagates from left to right. The ray passes through the optical beam splitter or circulator 6, towards the SBS material 4. Here again, a reflected ray of wavelength λ_1 is created. The optical beam splitter or circulator 6 does not transmit

the reflected ray, but rather reflects it to a different path, schematically shown as downwards.

A configuration which also includes an optical amplifier 8, is shown in Fig. 3. Here, the incident ray (at the left) of wavelength λ_0 has relatively low power. Thus, it is propagated through an optical amplifier 8, which could be an optical fiber, a bulk material or other optical material, to obtain a ray having the same wavelength but higher power. This higher power ray is then incident on an SBS device 2, similar to that shown in Fig. 2.

Fig. 4 is a schematic illustration of a cascaded system according to the present invention, comprising a plurality of SBS devices 2. Each output ray having a specific wavelength, emerging from an SBS device 2, serves both as one of the output rays for the cascaded system, and as a source ray for the next SBS device. In this manner, multiple rays, each having a distinct wavelength, are obtained. Here, each of the individual SBS devices 2 is composed of an optical fiber wound around a spool 10. In the embodiment of Fig. 4, temperature stabilization is obtained by the proper design and selection of the fiber material parameters (mostly temperature dependence of the refractive index) and the spool materials (mostly expansion coefficients) and dimensions.

Fig. 5 is a schematic illustration of a cascaded configuration of SBS devices 2, wherein alternating devices 2 are composed of two different materials 4, 4′, one having an increasing refractive index with temperature, and the other having a decreasing refractive index with temperature. In this embodiment, temperature constant displacements or spacings are obtained.

Fig. 6 shows a cascaded configuration similar to that of Fig. 5, albeit with additional optical amplifiers 8 in the SBS devices 2. Other numbers and placements of amplifiers 8 along the ray paths are also possible.

Fig. 7 illustrates an acousto-optical wavelength-shifting device 12, in which an input ray of wavelength λ_0 is incident upon an acousto-optical material 14. The scattered or reflected ray, propagating from right to left, has a slightly different output wavelength λ_1.

A similar acousto-optical wavelength shifting device 12, with an additional optical amplifier 16 for the input ray, is shown in Fig. 8. Here, the incident ray (at the left) of wavelength λ_0 has relatively low power. Thus, it is propagated through an optical amplifier 16 to obtain a ray having the same wavelength but higher power. This higher power ray is then incident on an acousto-optical wavelength-shifting device 12, similar to that shown in Fig. 7.

Fig. 9 is a schematic illustration of a cascaded configuration of acousto-optical wavelength devices 12, comprising a multiplicity of the devices shown in Fig. 7. Each output ray, having a specific wavelength emerging from an acousto-optical wavelength shifting device 12, serves both as one of the output rays for the cascaded system, and as a source ray for the next acousto-optical wavelength shifting device 12. In this manner, multiple rays, each having a distinct wavelength, are obtained.

Fig. 10 shows a cascaded configuration similar to that of Fig. 9, with an additional optical amplifier 18 in each of the individual acousto-optical wavelength shifting devices. A combination of acousto-optical wavelength shifting devices, with and without optical amplifiers, is also possible.

Fig. 11 is a schematic illustration of an optical parametric oscillator (OPO) 20. Here, an incident ray with wavelength λ_0 is transformed into a ray having a different wavelength λ_1. The wavelength change, in this embodiment, can be significantly larger than that obtained using SBS or acousto-optical devices 12.

Fig. 12 illustrates a system having a combination of OPOs 20 and acousto-optical wavelength shifting devices 12 or SBS devices 2. Here, a single input

ray, of wavelength λ_0, is used. The ray is first split into three ray portions λ_0', λ_0'', λ_0'''. The first portion λ_0' is applied directly into a SBS device 2 or an acousto-optical wavelength-shifting device 12, to obtain a multiplicity of rays having the wavelengths λ_1-λ_3. The second ray portion λ_0'' is first transformed by an OPO 20 to a ray having wavelength λ_4, which in turn is incident on another SBS device 2 or an acousto-optical wavelength-shifting device 12, to obtain a multiplicity of rays having wavelengths λ_5-λ_7. The third portion λ_0''' is first applied directly into a SBS device 2 or an acousto-optical wavelength-shifting device 12, to obtain a multiplicity of rays having wavelengths λ_8-λ_{10}; these rays are then transformed by an OPO 20 to obtain output rays having wavelengths λ_{11}-λ_{13}. Other combinations of OPO 20, SBS devices 2 and acousto-optical wavelength shifting devices 12 are also possible.

Fig. 13 is a schematic illustration of a system 22, wherein a single input ray of wavelength λ_0 is transformed into a series of separated rays having different output wavelengths; in this specific embodiment, ten wavelengths λ_1-λ_{10}. The system 22 may include cascaded SBS devices 2 or cascaded acousto-optical wavelength shifting devices 12, or a combination of those with OPOs 20. Also, the input wavelength λ_0 may be equal to one of the output wavelengths λ_1-λ_{10}.

Fig. 14 is a schematic illustration of a system 22, wherein a single input ray having wavelength λ_0 is transformed into a series of separated rays having different output wavelengths as shown in Fig. 12, but each of the output rays is modulated by a modulator 24. When all of the output rays are modulated, the number of modulators is the same as the number of output rays. Here again, the system 22 may include cascaded SBS devices 2, cascaded acousto-optical wavelength shifting devices 12, or a combination of those with OPOs 20. Also, the input wavelength λ_0 may be the same as one of the output wavelengths λ_1-λ_{10}.

Fig. 15 is a schematic illustration of an optical de-multiplexing system. An incident ray of light 26, composed of a multitude of wavelengths, is illuminated on a

wavelength dispersive component 28, such as a grating or a prism. Component 28 splits, by diffraction, the incident ray 26 into a series of rays, each having a different wavelength. These rays, each propagating in a slightly different direction, are incident upon a receiver 30 and split into different output fibers, causing different output fibers to contain rays of different wavelengths. Optionally, as illustrated in Fig. 16, the receiver 30 can be physically moved by an actuator 32; similarly, the component 28 can be tilted by an actuator 34 in order to change the direction of the diffracted rays so as to match the incident wavelengths to given output channels.

Fig. 17 illustrates an optical de-multiplexing system in which the incident ray of light 26 passes through an acousto-optical wavelength shifting device 36, which changes the wavelengths so that slightly different wavelengths are diffracted from component 28, leading to a slight change of the diffraction angles of different wavelengths.

Fig. 18 is a schematic illustration of an optical de-multiplexing system having a feedback control loop 38, wherein two detectors 40, 42 are positioned on two sides of one of the output channels which serves as the control loop. The powers in the two detectors 40, 42 are compared by control loop 38, which changes the tilt of the grating by means of actuator 34 accordingly, to obtain a nearly equal power in the two detectors. Moreover, specific modulation or specific data formats in the control loop 38 may differentiate it from other channels, so the control loop can be readily found.

Fig. 19 illustrates an optical de-multiplexing system having a feedback control loop 44, wherein a single detector 46 detects the output power in the control channel 48. The control loop 44 maximizes the output in channel 48. Control channel 48 may have a specific, known modulation, so as to allow for its identification, using techniques such as matched filtering.

Fig. 20 illustrates a multi-cascaded, multi-wavelength optical source 50. A ray having wavelength λ_0 injects into the first wavelength-shifting component 52, which

may be composed of SBS devices or acousto-optical wavelength shifting devices, or a combination of these, with or without optical amplifiers. Each wavelength-shifting component 52 introduces a new wavelength, to obtain, in a cascaded configuration, the first series of wavelengths λ_0-λ_8. Now, the last wavelength λ_8 in the first series is injected again into the first wavelength-shifting component 52. By this multi-cascaded configuration, other series of wavelengths are created. In order to control the number of series, a filter 54 is inserted, to allow only selected wavelengths to pass. Each of the rays outputted from the wavelength shifting component 52 now contains several different wavelengths, according to the number of series (In the embodiment shown, there are three series.) In order to obtain separated wavelength channels, one introduces a simple optical de-multiplexer 56 to each of the output rays, thus obtaining a large number of wavelengths with a relatively small number of components.

It will be evident to those skilled in the art that the invention is not limited to the details of the foregoing illustrated embodiments and that the present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

WHAT IS CLAIMED IS:

1. An optical system for converting an input ray of light having a single wavelength into a plurality of spatially or angularly displaced output rays, each having a different wavelength, said system comprising:

an array of a plurality of acousto-optical and/or stimulated Brillouin scattering (SBS) wavelength displacing devices in optical communication with each other,

whereby variations in the wavelength of said input ray or in temperature or strain of said devices will cause the wavelengths of said output rays to uniformly vary, thus maintaining constant intra-wavelength spacings between said output rays.

2. The system as claimed in claim 1, further comprising an optical beam splitter or circulator located along the input and output paths of the rays to and from said wavelength displacing devices, for reflecting said output rays in directions different than the directions of said output paths.

3. The system as claimed in claim 1, further comprising an optical amplifier located along the path of said input ray.

4. The system as claimed in claim 1, wherein at least a part of an output ray from one of said wavelength displacing devices is utilized as an input ray to another of said devices, forming a cascaded optical system.

5. The system as claimed in claim 1, wherein said SBS device is composed of a wound optical fiber.

6. The system as claimed in claim 1, wherein said wavelength displacing devices are composed of different materials, one of said materials having an increasing refractive index with temperature change, and one having a decreasing refractive index with temperature change.

7. The system as claimed in claim 1, wherein an output ray for a first one of said wavelength displacing devices constitutes a source for a second one of said devices.

8. The system as claimed in claim 1, further comprising an optical parametric oscillator (OPO) located along the input and/or output paths of at least one of said wavelength displacing devices.

9. The system as claimed in claim 1, further comprising at least one modulator for modulating an output ray.

10. The system as claimed in claim 1, wherein said input ray is obtained from a tunable laser.

11. The system as claimed in claim 1, wherein said input ray is obtained from a fixed-wavelength laser.

12. The system as claimed in claim 1, wherein said input ray is obtained from one of a plurality of laser sources in optical communication with each other so that, upon the malfunctioning of one of said sources, at least one of the other sources is utilized.

13. The system as claimed in claim 10, further comprising at least one tunable laser for backup purposes.

14. The system as claimed in claim 5, wherein said fibers have a small core area and are selected from the group comprising photonic bandgap fibers and dispersion compensating fibers.

15. An optical de-multiplexing system for receiving a ray having a multitude of wavelength channels with known spacing between them and separating said channels into a series of rays having different wavelengths, said system comprising:

an actuator device for tuning the de-multiplexed wavelengths, wherein at least one of said wavelength channels acts as a control loop channel on which a closed control loop for locking the wavelength is activated.

16. The optical system as claimed in claim 15, wherein said multitude of wavelength channels with known spacing are obtained using an array of a plurality of acousto-optical and/or SBS wavelength displacing devices in optical communication with each other.

17. The optical system as claimed in claim 15, wherein said active device is a piezoelectric or magneto-restrictive actuator.

18. The optical system as claimed in claim 15, wherein data of said control loop channel has a specific modulation enabling it to be differentiated from neighboring channels.

19. The optical system as claimed in claim 15, wherein said closed control loop comprises two detectors and the wavelength of said control loop channel is between the two wavelengths detected by said two detectors.

20. The optical system as claimed in claim 15, wherein said actuator device rotates or moves a wavelength-dispersive component such as a grating or a prism.

21. The optical system as claimed in claim 15, wherein said actuator device moves or tilts a fiber array or a waveguide.

22. The optical system as claimed in claim 15, further comprising an acousto-optical wavelength shifting device, through which said ray is passed.

23. The optical system as claimed in claim 4, wherein the output of the last of said devices is connected, via a filter, to the input of the first of said devices, and wherein a de-multiplexer is connected to the output of at least one of said devices for producing multiple, separated wavelengths.

24. An optical system as claimed in claim 1, for connecting an input ray of light having a single wavelength into a plurality of spatially or angularly displaced output rays, each having a different wavelength, substantially as hereinbefore described and with reference to the accompanying drawings.

25. An optical de-multiplexing system as claimed in claim 15, for receiving a ray having a multitude of wavelength channels with known spacing between them and separating said channels into a series of rays having different wavelengths, substantially as hereinbefore described and with reference to the accompanying drawings.

for the Applicant:

WOLFF, BREGMAN AND GOLLER

by:

Fig. 1

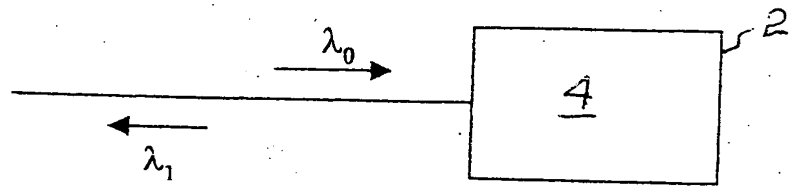


Fig. 2

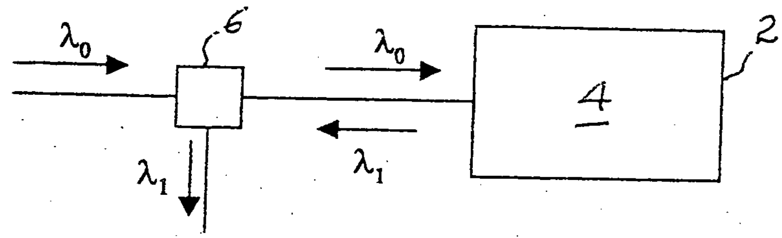
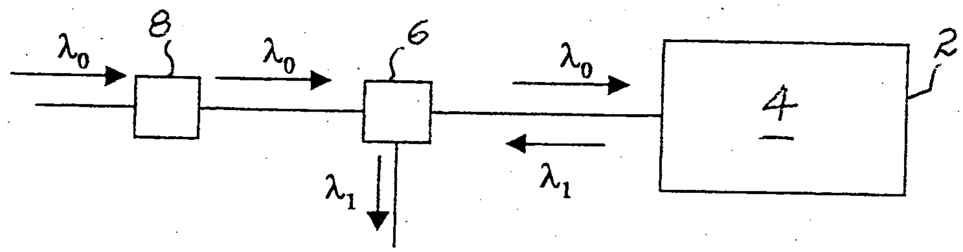


Fig. 3



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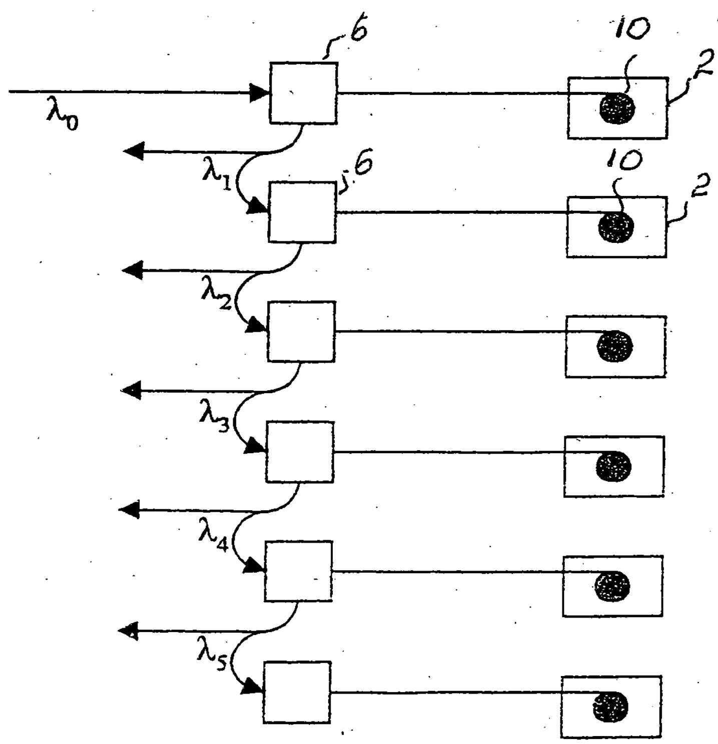


Fig. 5

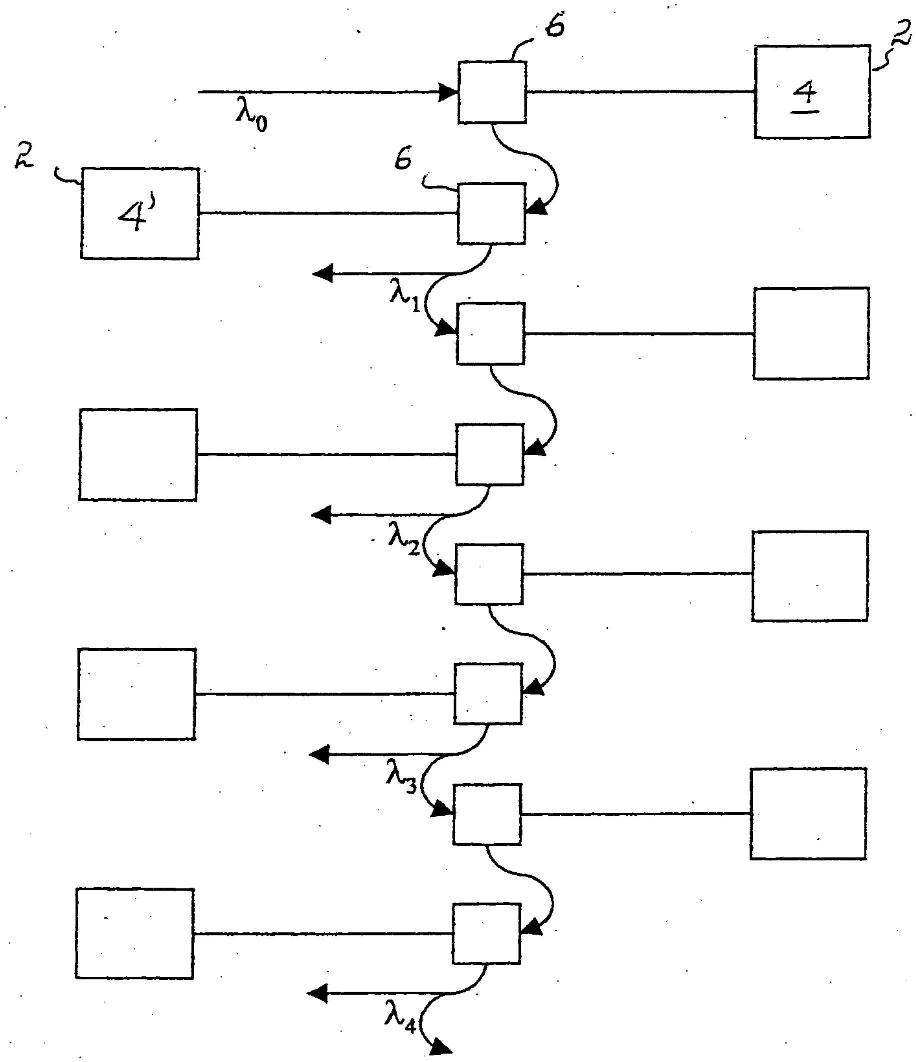
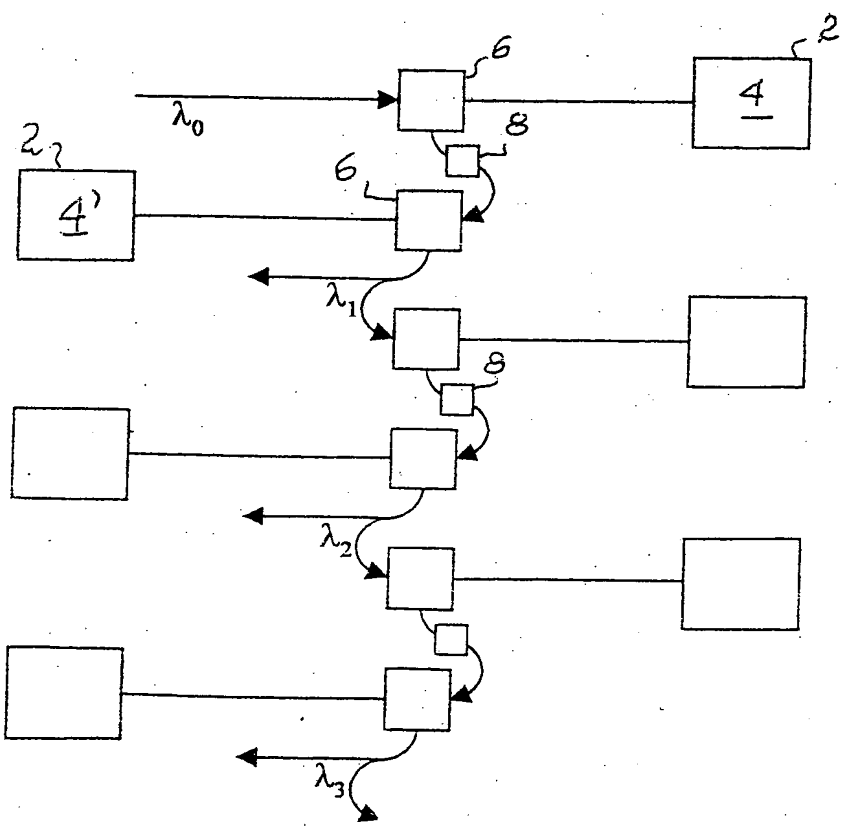


Fig. 6



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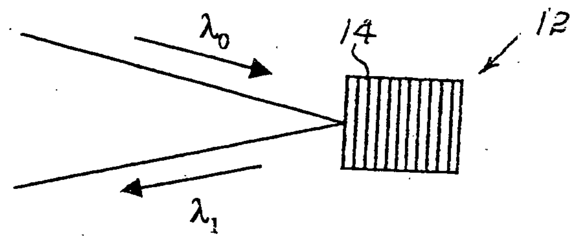

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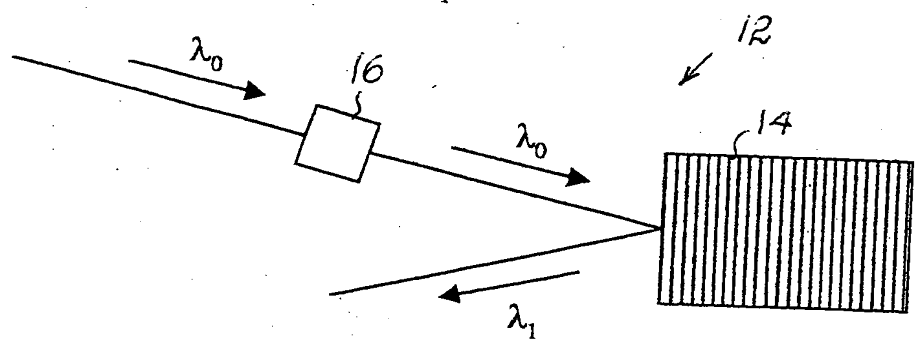

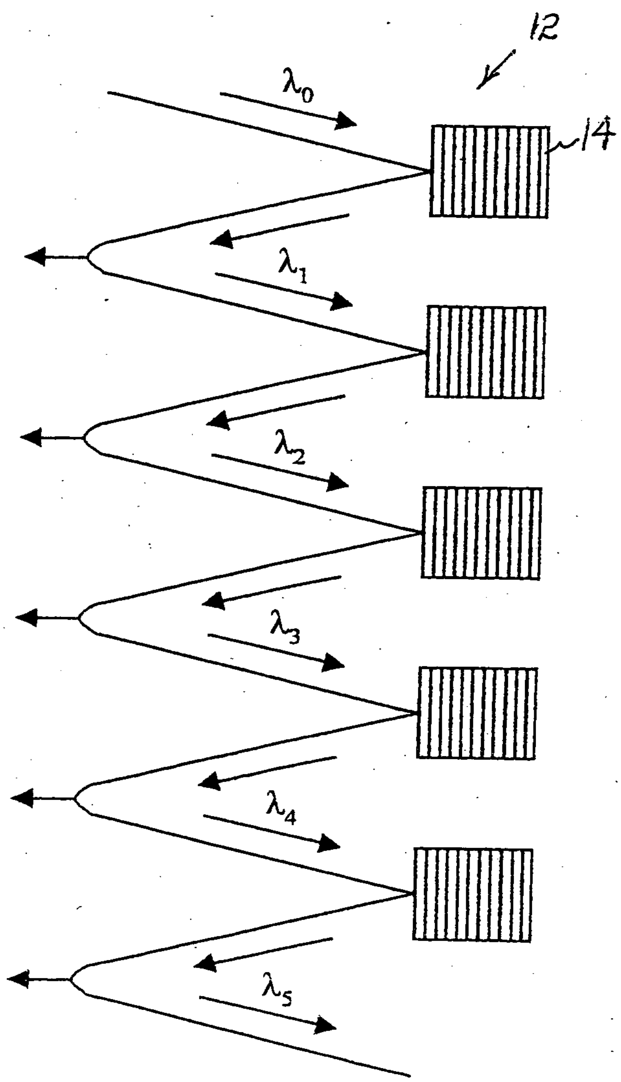

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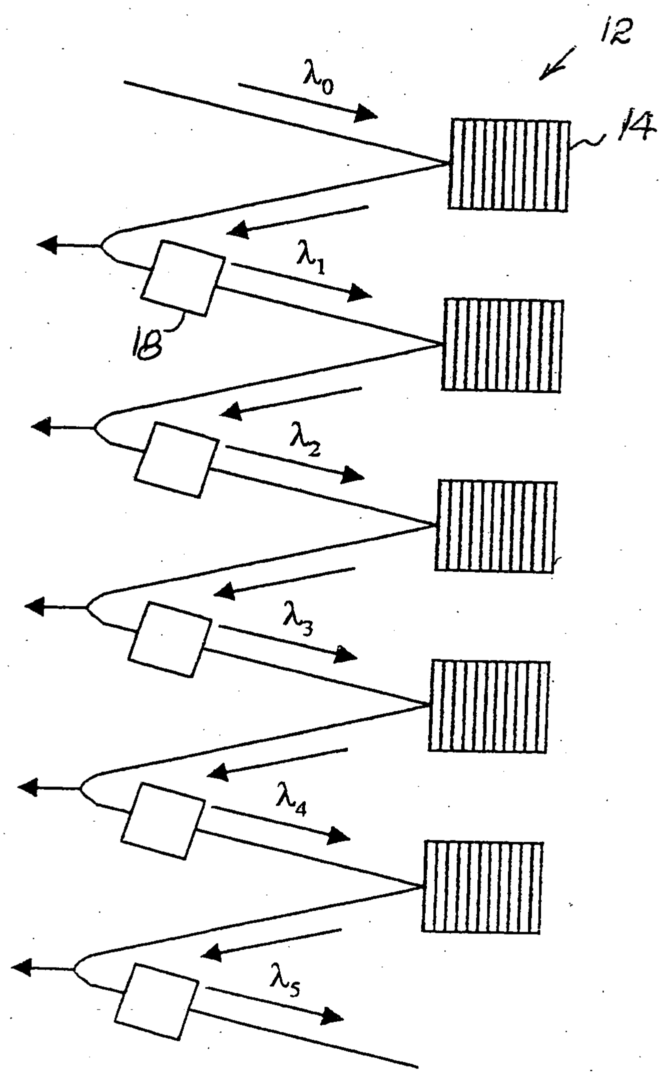
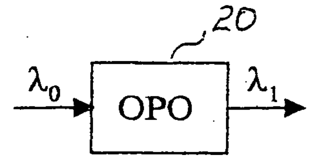


Fig. 10

Fig. 11



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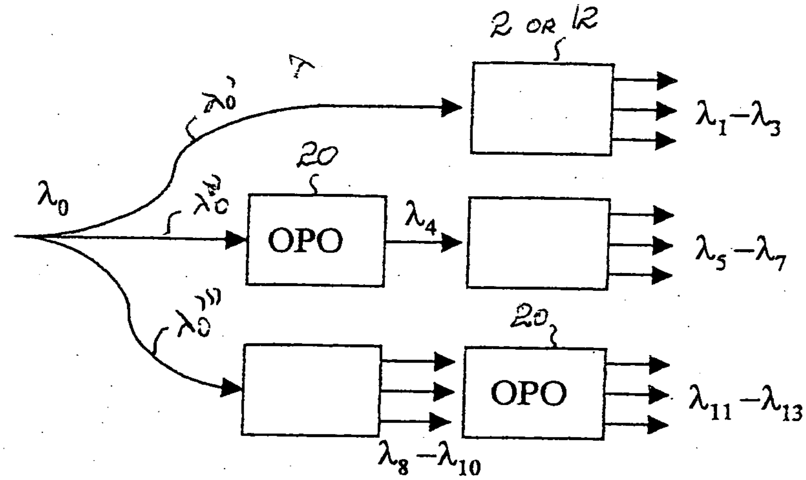

Fig. 13

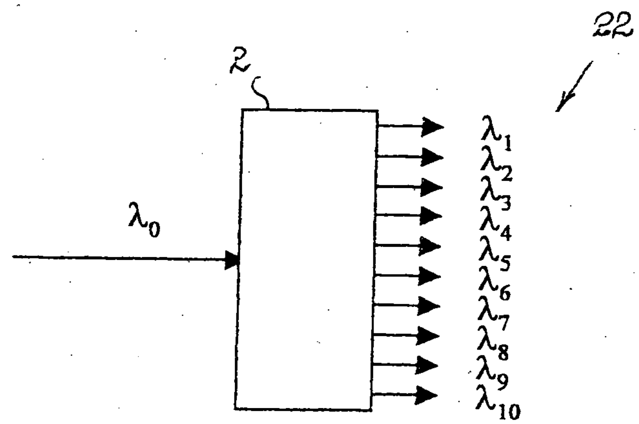

Fig. 14

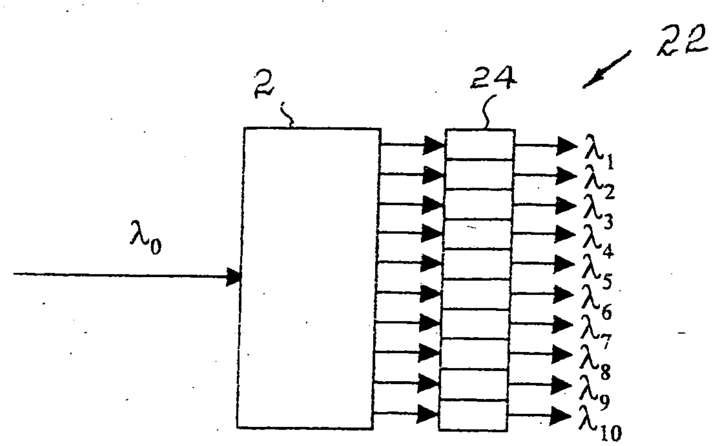

Fig. 15

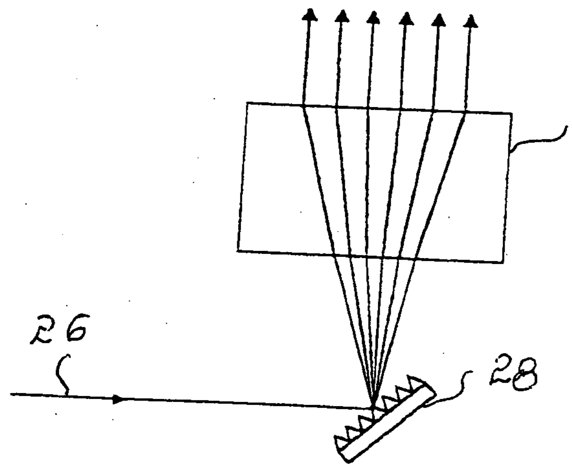

Fig. 16

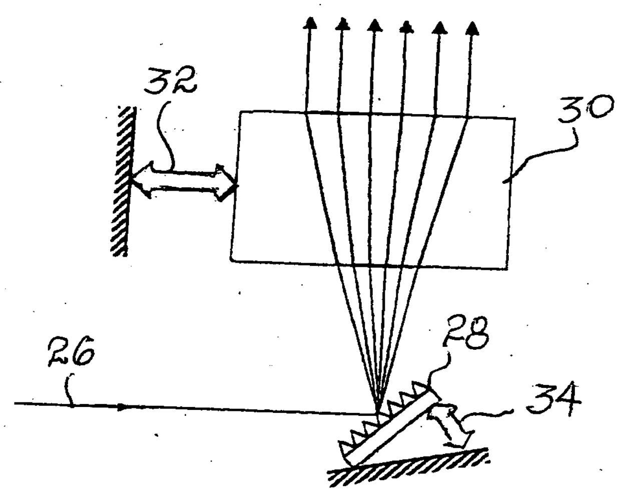

Fig. 17

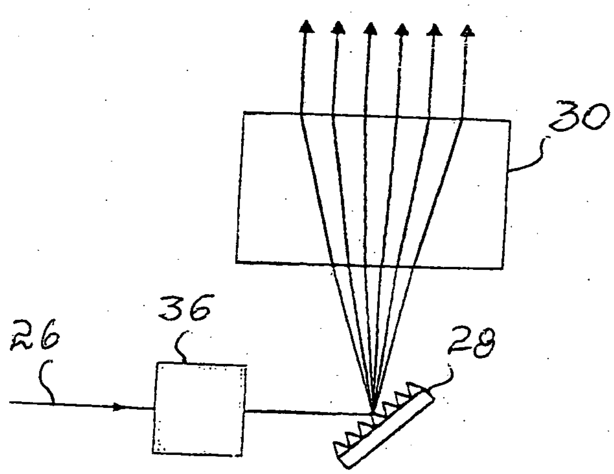

Fig. 18

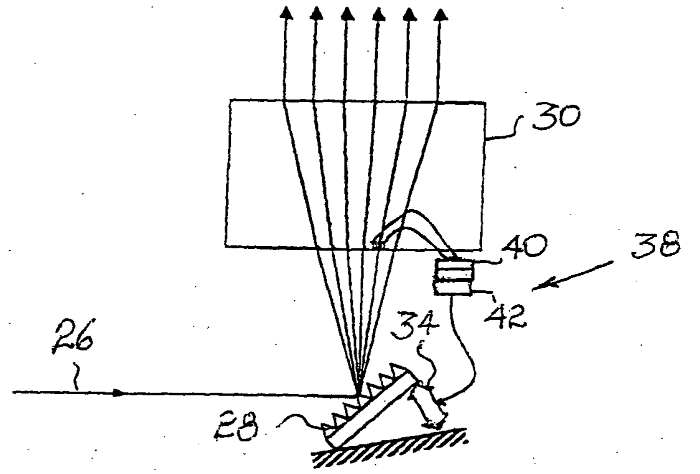

Fig. 19

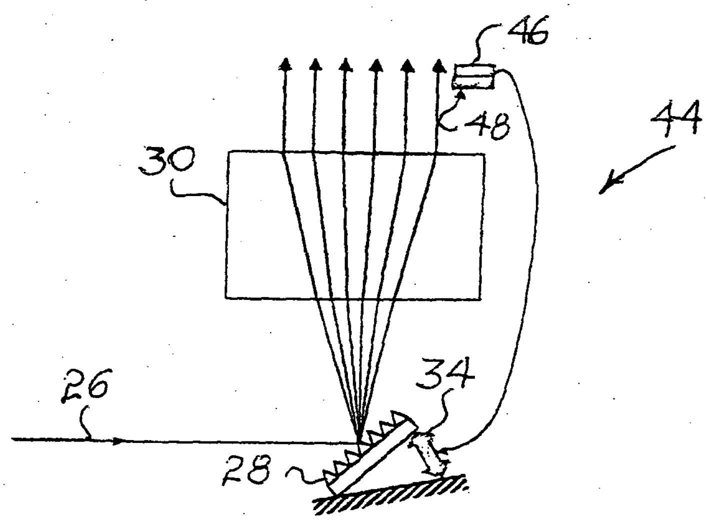

Fig. 20